The 2008 outburst floods from Ghulkin Glacier, Karakoram, Pakistan

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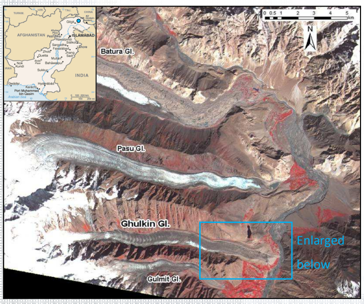
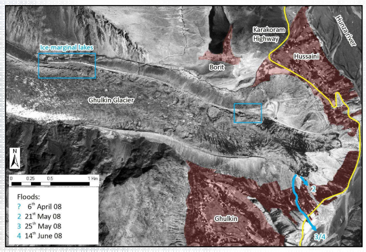
1. INTRODUCTION



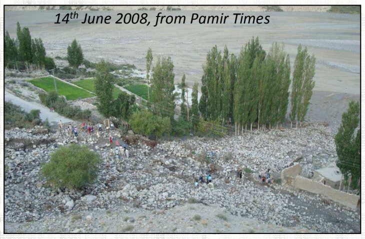
Glacier-related hazards have been recorded at the Batura, Ghulkin and Pasu Glaciers (see also Quincey & Richardson poster) in the upper Hunza valley, western Karakoram, through the late 20th Century to the present day. Here we document hazardous floods at Ghulkin Glacier in 2008 and discuss possible causal mechanisms.

2. ACCOUNT OF FLOOD EVENTS & DAMAGES



In 2008, floods from the south side of Ghulkin Glacier terminus (right) occurred on the 6th April, 21st May, 25th May and 14th June. Details of the 6th April event are not known, although losses of cattle were reported in the media. It is thought that the event on 21st May flowed mostly down the existing meltwater channel and caused no damage. The events on 25th May and 14th June were the largest, eroding a channel through part of Ghulkin village (below). Immediate impacts were the loss of livestock, orchards, arable crops, 4 houses, 6 cattle sheds and damage to the Karakoram Highway. Also, damage to 4 irrigation channels subsequently resulted in a drought in Borit village in 2009. Further, smaller-scale flooding occurred in spring 2009, causing distress and again damaging the Karakoram Highway.

25th May 2008, from Pamir Times



14th June 2008, from Pamir Times

3. FLOOD AND CHANNEL CHARACTERISTICS

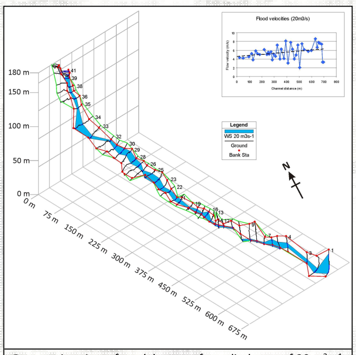
Ghulkin Gl. Terminus and breaches through the moraine crest

Trees stripped of bark by the sediment-laden flood

Two incisions through the southern moraine crest connect to the main flood channel (left). For the 5th May and 14th June events, witnesses describe floods lasting up to 24 hours with peak flows lasting about 1 hour. Stripped bark and clasts embedded on the up-slope side of trees (left) indicate that the initial flood wave was sediment-rich and in some places at least 2.2 m high.

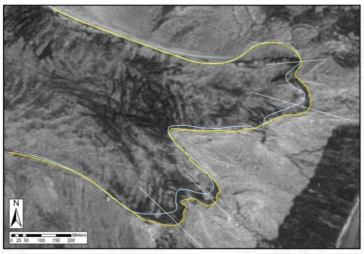
Channel characteristics and flood hydraulics have been investigated by field surveys (dGPS, sediment measurements) and 1-D modelling (right):

- A 680 m run-out and 192 m fall to the Hunza River (av. gradient 15.8°);
- Peak discharge ≈50 $m^3 s^{-1}$;
- Flood volume ≈1.0x10^6 m^3 (based on a 1 hour peak, 23 hour tail);
- Mean diameters of largest clasts are 0.9-0.5 m (fining down-valley).



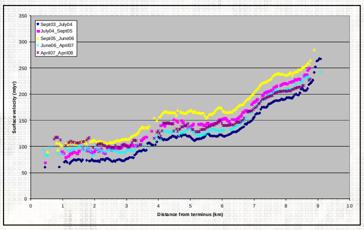
Perspective view of model output for a discharge of 20 $m^3 s^{-1}$ (nb. contained well within bank)

4. GLACIER DYNAMICS



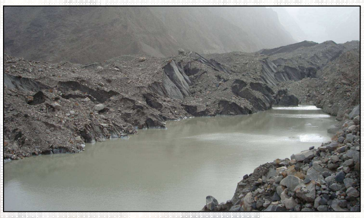
Frontal positions derived from multi-temporal satellite data (left) indicate a 50 m advance of the south lobe from 2004-2007 and 36 m advance of the north lobe from 2006-2008 (left, table). In 2008, the terminus was overriding the terminal moraine on the north side (below).

Fluctuations of the Ghulkin terminus during the period 2003-08 (+/- 5-10 m)		2003-04	2004-05	2005-06	2006-07	2007-08
Northern	Lobe 1 (N)	3	-9	-8	14	8
	Lobe 2 (S)	-13	8	0	16	20
Southern	Lobe 1 (N)	-6	-3	40	2	4
	Lobe 2 (S)	-2	17	15	21	0



Centreline velocities derived from optical feature tracking of multi-temporal SPOT satellite imagery show an increase in glacier-wide velocities between 2004 and 2006, and then an acceleration of the lower 3 km from 2007-2008 (right, middle).

Ice-marginal lakes containing turbid water were associated with the glacier acceleration in 2007-08. The one pictured (right) filled and drained twice at a similar time to the floods in the early summer of 2008.



5. DISCUSSION

We know with certainty that two of the four floods in 2008 (25th May, 14th June) eroded a channel to the south of the glacier, and that two transient ice-marginal lakes previously existed 1 km and 3 km up-glacier on the north side. Less certain is our understanding of the contribution, if any, of the lakes to the floods. For the 25th May and 14th June events, strandlines and 1-D modelling suggest possible peak discharges of 50 $m^3 s^{-1}$ and flood volumes of 1x10^6 m^3. Even allowing for a re-worked sediment component of 40%, the estimated flood volume far exceeds (≥ x5) the volume of the largest ice-marginal lake (≈1.3x10^5 m^3). It is probable that there was a significant sub-/en-glacial component to the floods, in addition to any contribution from the lakes. Reorganisation of conduits during glacier advances has been proposed previously to explain glacier outbursts and transient ponding of turbid water in supraglacial and ice-marginal positions[1].

Periodic flooding from Ghulkin Glacier may continue whilst terminus velocities remain high. The current advance and associated hazards appear to be part of a recurring cycle since the late-20th Century: advances in the 1980s and again in 1998/99 were associated with rock fall and floods[2,3].

A similar pattern of glacier acceleration in 2004-2006 has been recorded for Baltoro Glacier, which has been tentatively linked to increased basal sliding following heavy snow fall in 2004/05[4]. Despite different glacier styles, regional climatic events may be driving synchronous glacier (and hazard) responses.

6. CONCLUDING REMARKS

Floods causing local damage that are associated with advancing glaciers have received little attention in the high-mountain regions of Asia compared to larger moraine-dammed lake outbursts (which are very rare in the Karakoram). The outputs from this project are being shared with stakeholders in Pakistan to help develop glacier risk management responses and strategies.

References: [1]Haeberli *et al.* 2002. *Norsk Geog. Tidsskrift* **56**:104-111. [2]Goudie et al. 1984. *Proc. of the Int. Karakoram Project*. pp359-410. [3]Kenneth Hewitt, pers comm. [4]Quincey *et al.* In Press. *J. of Glaciology*.